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ANALYSIS OF D CONVERTER

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ABSTRACT

This paper analyses a D type dc-dc converter, which has low input current ripple along with continuous input and output energy flow. Conventional dc- dc converters connected to the non-linear loads suffer from high power losses and may require electrolytic filtering capacitor due to high input current ripples. The D type dc-dc converter does not require any filtering capacitor across the load and can be used either in buck mode or in boost mode. Though the D type converter was already developed but its analysis to develop state space model is not available in the current literature. This paper explains the procedure of state space representation of the D type converter. The simulations are performed based on the state space model and the results are compared with other continuous input and output converters.

KEYWORDS: DC-DC Converters, Input Current Ripple & State Space Averaging

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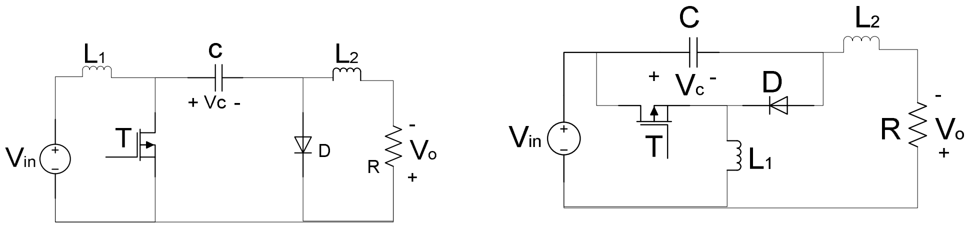
Original Article

INTRODUCTION

DC-DC converters are used to convert unregulated DC voltage [I] into a regulated DC voltage whose output voltage magnitude differs from input voltage. These converters are widely used in many applications like switched mode power supplies (SMPS) [II], adjustable speed drives [III] etc. There are many DC-DC converters available in the literature. Few of the popular converters among them are buck, boost, buck-boost, SEPIC [IV], Cuk [V], C and D converters [VI]. Out of these Cuk, C and D converters offers continuous input and output energy flow [VII] which is given in Figure 1. This is one of the important requirements for most of the applications, so these converters are mostly used. However, C converter has high input current ripple, Cuk converter has both high current and voltage ripple. Due to the presence of high input current ripple, lifetime of the sources will be reduced. High input current ripple also increases the power loss and is difficult to design closed loop controller coefficients for stable operation [VIII] and [IX]. The D type converter offers little input current ripples compared to Cuk and C type converters

Most of the converters are usually operated with closed loop controller [X] either to control the output voltage or current for LED drivers/constant power controllers or for maximum power tracking while using renewable power generation systems. For efficient design of closed loop control parameters, mathematical representation of the physical system is important. Hence, this paper develops state space model of D –type converter using average state space model.



(a) **(b)**

Figure 1: Circuit Diagram of (a) Cuk Converter, (b) C Converter

D CONVERTER

The circuit representation of D type DC-DC converter with less input current ripple is shown in Figure. 2. This converter is proposed by A. H. El Khateb.et al. [VI].

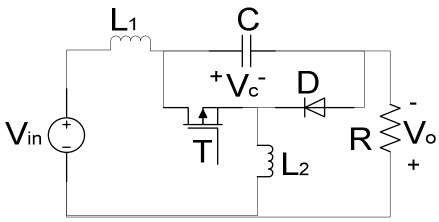


Figure 2: D Converter

This converter consists of same number of components as that of the converters shown in Figure 1. But, the amount of input current ripple is less when compared to conventional converters. In this, the inductor L_1 contributes at the input side whereas inductor L_2 is shared to both input side and output side through the switch, T and diode, D and hence the input current is reduced.

ANALYSIS OF D CONVERTER

The D converters, shown in Figure 2 have two modes of operations. In the first mode (ON state) the switch T is ON and the diode D is reverse biased thus the inductor L_2 is connected at input side and draws current from the source. The practical circuit of proposed converter in ON state by considering the parasitic resistance is shown in Figure 3. In the second mode (OFF state) the switch T is OFF, the diode D is forward biased and the inductor connects at the output side. This makes the inductor to discharge through the load. The practical circuit of proposed converter in OFF state by considering the parasitic resistance is shown in Figure 4.

MODE1: ON STATE

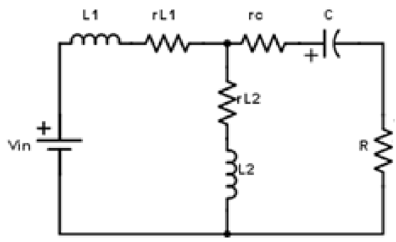


Figure 3: ON State Diagram of D Converter

The ON state equations of D type Converter are given as below.

$$r_{L_1} i_{L_1} + L_1 \frac{di_{L_1}}{dt} + r_{L_2} i_{L_2} + L_2 \frac{di_{L_2}}{dt} - v_{in} = 0 \tag{1}$$

$$\frac{dv_c}{dt} cr_c + v_c - v_o - L_2 \frac{di_{L_2}}{dt} - r_{L_2} i_{L_2} = 0 \tag{2}$$

$$r_{L_1} i_{L_1} + L_1 \frac{di_{L_1}}{dt} - v_{in} + \frac{dv_c}{dt} cr_c + v_c - v_o = 0 \tag{3}$$

The steady state model of the D converter in the ON state can be obtained from the above equations and it is shown in equation (4).

$$A_1 = \begin{bmatrix} \frac{-R - r_c - r_{L_1}}{L_1} & \frac{R + r_c}{L_1} & \frac{-1}{L_1} \\ \frac{R + r_c}{L_0} & \frac{-R - r_c - L_0}{L_0} & \frac{1}{L_0} \\ \frac{1}{C} & \frac{-1}{C} & 0 \end{bmatrix} B_1 = \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \end{bmatrix} C_1 = \begin{bmatrix} -R & R & 0 \end{bmatrix} \tag{4}$$

MODE2: OFF STATE

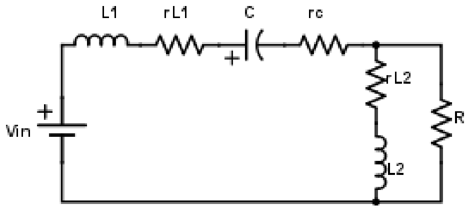


Figure 4: OFF State Diagram of D Converter

The OFF state equations of D type Converter can be written as follows.

$$r_{L_1} i_{L_1} + L_1 \frac{di_{L_1}}{dt} - v_{in} + \frac{dv_c}{dt} cr_c + v_c = 0 \tag{5}$$

$$v_o + L_2 \frac{di_{L_2}}{dt} + r_{L_2} i_{L_2} = 0 \tag{6}$$

$$r_{L_1} i_{L_1} + L_1 \frac{di_{L_1}}{dt} - v_s + \frac{dv_c}{dt} cr_c + v_c - v_o = 0 \tag{7}$$

The steady state model of the D converter in OFF state can be obtained from the above equations and it is shown in equation (8).

$$A_2 = \begin{bmatrix} \frac{-R - r_c - r_{L_1}}{L_1} & \frac{R}{L_1} & \frac{-1}{L_1} \\ \frac{R}{L_0} & \frac{-R - r_{L_0}}{L_0} & 0 \\ \frac{1}{C} & 0 & 0 \end{bmatrix} B_2 = \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \end{bmatrix} C_2 = \begin{bmatrix} -R & R & 0 \end{bmatrix} \tag{8}$$

The average state space model is obtained using the formulae which is shown below.

$$\begin{aligned} A &= A_1 d + A_2 (1 - d) \\ B &= B_1 d + B_2 (1 - d) \\ C &= C_1 d + C_2 (1 - d) \end{aligned} \tag{9}$$

Thus, the average state space model of the D converter can be written as

$$A = \begin{bmatrix} \frac{-R - r_c - r_{L_1}}{L_1} & \frac{r_c d}{L_1} + \frac{R}{L_1} & \frac{-1}{L_1} \\ \frac{r_c d}{L_0} + \frac{R}{L_0} & \frac{-R - r_{L_0}}{L_0} - \frac{r_c d}{L_0} & \frac{d}{L_0} \\ \frac{1}{C} & \frac{-d}{C} & 0 \end{bmatrix} \quad B = \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \end{bmatrix} \quad C = \begin{bmatrix} -R & R & 0 \end{bmatrix} \tag{10}$$

The state space equations from the average state space model is given as below.

$$\begin{bmatrix} \overline{x_1} \\ x_2 \end{bmatrix} = \begin{bmatrix} \frac{-r_L}{L} - \frac{ar_c}{L}(1-d) & \frac{ar_c}{RL}(1-d) \\ \frac{a}{C}(1-d) & -\frac{a}{RC} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{L} - \frac{ar_c}{RL}(1-d) \\ \frac{a}{RC} \end{bmatrix} \mathrm{V_{in}} \tag{11}$$

$$\mathrm{V_0} = \begin{bmatrix} R(1-a)(1-d) & ad \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} a \\ 0 \end{bmatrix} \mathrm{V_{in}} \tag{12}$$

The parameters of the D converter used for MATLAB simulation is given in Table 1. [VI].

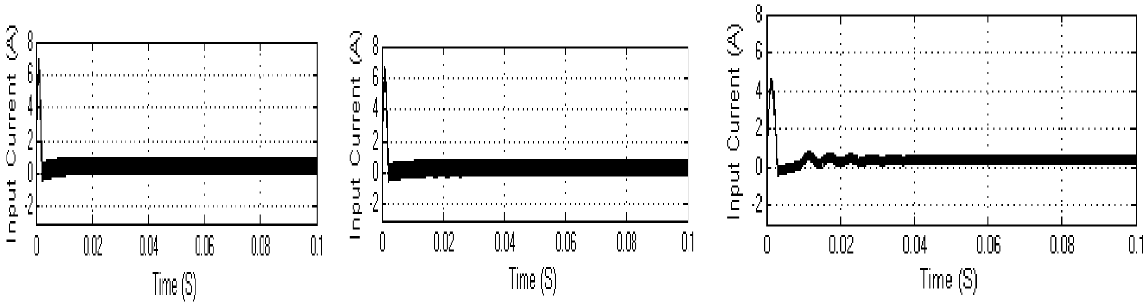
Table 1: D-Converter Parameters

Inductor	L_1	1.0mH
Inductor	L_2	1.0mH
Capacitor	C	10µF
Switching frequency	f_s	50kHz

SIMULATION RESULTS

The matlab based simulations are performed on D-type dc-dc converter using the state space equation (11) and (12). For comparison Cuk, and C type converter MATLAB based simulation models were developed as shown in Figure 1 and Figure 2. In order to identify the input current ripple, the input current waveforms of the Cuk, C and D converters are shown in Figure 5. These are simulated waveforms obtained by operating the converters at a duty ratio of 0.5. Here, the input voltage is taken as 24V. In order to show the efficacy of the system, the cuk, C and D type converters input current ripple is given in Table 2. From this table it is clear that the D-type converter has minimum current ripples compared to other converters irrespective of the operating duty ratio. After D-type converter, the C-type converter is superior to cuk in terms of input current ripples. The input current ripple listed in table 2 is calculated using the following equation:

$$\Delta i_{ripple} = i_{max} - i_{min}. \tag{13}$$



(a) (b) (c)

Figure 5: Input Current of (a) Cuk Converter, (b) C Converter, (c) D Converter

Table 2: Input Current Ripples of Cuk, C and D converters

Duty Ratio	Cuk	C	D
0.1	0.209	0.209	0.0844
0.2	0.43	0.41	0.171
0.3	0.61	0.6	0.252
0.4	0.89	0.8	0.35
0.5	1.1	0.61	0.44
0.6	1.25	1.4	0.6
0.7	1.3	1.4	0.56
0.8	1.6	1.6	0.68
0.9	1.6	1.75	0.62

CONCLUSIONS

This paper develops state space model of the D-type converter by state space averaging technique. Simulations are performed based on the state space model and the results are compared with the Cuk and C type converters. The results show that the D type converter has less input current ripples followed by C and cuk type converter.

REFERENCES

1. *Robert W. Erickson "DC-DC Power Converters," Article in Wiley Encyclopedia of Electrical and Electronics Engineering.*
2. *Ulf Schwalbe et al. (2008). Comparison of different three-stage DC-DC converter solutions for SMPS applications, IEEE International symposium on Ind. Electronics, Cambridge, 178–183, June 30-July 2nd, 2008.*
3. *Sanjeev Singh, Bhim Singh. (2010). A Voltage Controlled Adjustable Speed PMBLDCM Drive using A Single-Stage PFC Half-Bridge Converter, Applied Power Electronics Conference on Exposition (APEC) Palm Springs, CA, 1976–1983, 21-25.*
4. *E. Babaei and M. Mahmoodieh (2014). Calculation of output voltage ripples and design considerations of SEPIC converter, IEEE Trans. Ind. Electron., 61(3), 1213–1222.*
5. *Satyajit Chincholkar, Chok-You Chan (2015). Design and implementation of an output feedback controller for the Cuk converter IEEE conference on Industrial Electronics Society (IECON 2015), Yokohama, 000086– 000090, 9-12.*
6. *A. H. El Khateb et al. (2015). DC-to-DC Converter With Low Input Current Ripple for Maximum Photovoltaic Power Extraction IEEE Trans. Ind. Electron., 62(4), 2246–2256.*
7. *B. Williams (2013).DC-to-DC converters with continuous input and output power IEEE Trans. Power Electron., 28(5), 2307–2316.*
8. *J. Knight et al. (2006). An improved reliability Cuk based solar inverter with sliding mode control IEEE Trans. Power Electron., 21(4), 1107–1115.*

9. *N. Benavides and P. Chapman (2008). Modeling the effect of voltage ripple on the power output of photovoltaic modules IEEE Trans. Ind. Electron., 55(7), 2638–2643.*

10. *Koduri. Omkar, Vardhani Ambati (2014), Closed Loop Control of ZVS, ZCS Interleaved Boost - Converter With PID Controller, International Journal of Electrical and Electronics Engineering Research, 4(1), 23-24.*